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Downscaling methodology to produce a high resolution gridded emission inventory to support local/city level air quality policies

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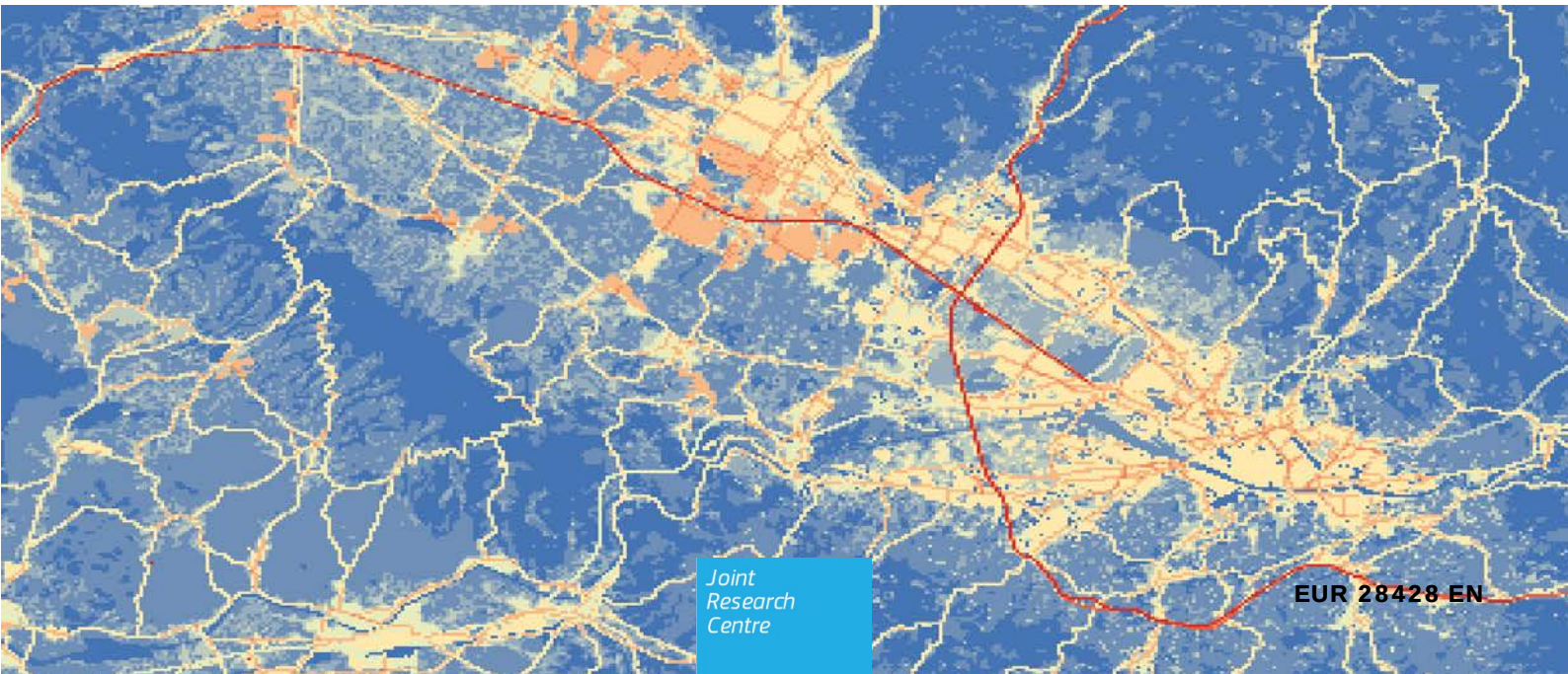

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Abstract

This report introduces a Top Down emission inventory covering the EU28 domain developed with the goal of supporting integrated assessment modelling strategies (IAM) in the fields of regional air-quality, land use and territorial modelling.

The high resolution JRC inventory is based on country total emission data derived from the Greenhouse Gas and Air Pollution Interactions and Synergies Model (GAINS) set for reaching the targets under the assumptions of the 2013 Air Quality package review. The JRC inventory provides emissions for a wide array of sectors from year 2010 up to 2030 and covers NO_x, SO_2, VOC, PM_{10}, $PM_{2.5}$ and NH_3. It is developed at 100m spatial resolution and is currently distributed at $1/8^o$ x $1/8^o$ degrees resolution.

In order to spatially distribute emissions, the specific spatial layers, model outputs or statistical datasets which best reproduce the expected spatial patterns of emissions are selected for each sector. The choices made in terms of calibration of these spatial proxies are also introduced and discussed.

1 Introduction

The aim of this work is to formalize and apply a downscaling methodology to disaggregate atmospheric emissions from the national scale to grid level. This refined product represents an essential input for detailed air-quality models which simulate source-receptor dynamics and consequent pollutants concentrations.

In Europe, regional and local emission inventories are managed and compiled by several different agencies which rely on different standards, methods and categories. In some cases, this can yield to a heterogeneous and inconsistent picture when collating these data for usage in continental scale approaches.

There have been several implementations of this kind of top-down approach, where national emissions estimates are downscaled at a finer resolution (Beelen et al., 2009; Crippa et al., 2016; Theloke et al., 2009, Theloke et al., 2012; Kuenen et al., 2014; Janssens-Maenhout et al., 2015).

The main reason for developing a new European emission inventory is the need to have an inventory interacting with the LUISA platform[1] (Lavalle et al., 2013) to provide input to the Integrated Assessment Models (IAM) SHERPA (Thunis et al., 2016) and RIAT+ (Carnevale et al., 2012) tools.

The Land Use Integrated System Platform (LUISA) is an integrated framework in "support to the conception, development, implementation and monitoring of EU policies" (Lavalle et al., 2011). Such a framework is based upon the integration of spatially explicit land use models with other modelling activities in thematic fields such as economy, demography, climate, hydrology, agriculture and forestry. The main outputs of the modelling platform are population density and land use changes for scenarios from year 2010 up to 2050.

These layers become the main inputs for the generation of emissions for our down-scaling approach which covers scenarios until year 2030. As input to the IAM tools, a very detailed thematic (sectoral) disaggregation would also be needed to account for the cost-benefits analysis of abatement measures. However this information is not readily available in currently existing inventories. This is one of the reason motivating the development of this JRC inventory.

This report aims to provide an in-depth insight into the technical aspects of the downscaling process. For each sector, the choices made regarding the input datasets are explained, also detailing how specific weights reproducing the spatial patterns of activity intensity (e.g.: Daily traffic; Yield rate; Livestock Density) have been estimated.

2 Methodology

2.1 Input emission data

The aim of this work is to design and implement a disaggregation methodology to downscale modelled air emissions from the national scale to gridded data.

The novelty of our approach relies on the very high spatial resolution of the LUISA platform (100m) and its ability to model scenarios up to 2050. The emission data used as input in our emission model are the GAINS country totals (Greenhouse Gas and Air Pollution Interactions and Synergies Model**,** Amann et al., 2011), available at a high level of sectoral aggregation, detailing a large set of sector-activity combinations for multiple years and several chemicals.

[1] https://ec.europa.eu/jrc/en/luisa

The JRC inventory is for now released at two diifferent spatial resolutions, 0.0625 and 0.1 degrees for the year 2010. The multi-temporal dataset, for scenarios up to year 2030, is not presented in this report.

GAINS is chosen as source of the modelled emission data because it 'combines information on economic and energy development, emission control potentials and costs, atmospheric dispersion characteristics and environmental sensitivities towards air pollution' (Schöpp et al, 1998). Among the different scenario options available in GAINS, our basecase scenario was set to match the reference one used in LUISA (Lavalle et al., 2013), under the assumptions of the 2013 Air Quality package review and it is aligned with the EU Energy, transport and Greenhouse Gases emissions trends to 2050.

It implements the EU 20-20-20 targets of 20% reduction in CO_2 emissions in 2020 with respect to 1990 levels, - 31% reduction in 2030, and -43% in 2050; ETS emissions 31% lower in 2020 than in 2005; 20% energy efficiency (aligned with national plans) in 2020; and 20% RES-e in 2020 in line with national plans.

2.2 Proxies and surrogates

The disaggregation of national emission data is based on the usage of spatial surrogates as explained in Maes et al., 2009. A spatial surrogate is a value between zero and one which represents the fraction of the national total to be assigned to the considered pixel (Eyth and Habisak, 2003).

The generation of this large number of surrogates involves the combined usage of different proxies acquired from several statistical databases, spatial datasets and linked external models.

When these surrogates are the output of simulations done with multi-temporal models, we are able to generate 'dynamic' proxies matching the year of the simulation performed by GAINS (e.g.: CAPRI for the agricultural sector, LUISA for population density and land use, TREMOVE for traffic shares). In the other cases, we have to rely on 'static' proxies, which have to be assumed to be constant from year to year (e.g.: livestock densities (FAO), road networks (OSM contributors, 2015), employment and airport traffic statistics (EUROSTAT)).

In order to disaggregate each single GAINS sector/activity combination, 63 different surrogates have been developed. These surrogates are presented in the following chapters where we group the input sectors in SNAP97 (Selected Nomenclature for Air Pollution - CORe INventory AIR emissions, CORINAIR) Level 1 Macro sectors (Table 1); this nomenclature has been chosen to facilitate the comparison with other Top Down inventories that rely on the same classification.

SNAP	Sector Name
1	Combustion in energy and transformation industries
2	Non-industrial combustion plants
3	Combustion in manufacturing industry
4	Production processes
5	Extraction and distribution of fossil fuels
6	Solvent and other product use
7	Road transport
8	Other mobile sources and machinery
9	Waste treatment and disposal
10	Agriculture

Table 1: SNAP Nomenclature and categories

2.2.1 Macro Sector SNAP1 – Combustion in energy and transformation industries

This Macro Sector covers electricity production, petroleum refining, coke production and other energy industries. The GAINS sectors and activities included in this Macro Sector are detailed in Table 2 where they have been grouped by the surrogate layers built to downscale those emissions. A similar table will be included in the following chapters relative to each single Macro Sector.

For the electricity production sectors we rely on the information stored in the S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database. The S&P Global Platts Generating Stations data set contains point features representing power generating facilities in Europe. Detailed attribute information associated with the generating station dataset includes fuel types (primary and secondary), prime movers, operational status and Operating Net Capacity (MW).

Based on the processes (primary fuel types) available in this dataset, the power stations have been grouped in 5 categories according to the fuel: biomass, coal, gas, oil and waste. The information about the secondary fuel type is not taken into account at this stage while planned facilities are only present in scenarios for years 2020 and 2030. The plant-specific data about Operating Net Capacity (MW) constitutes the weight on the basis of which distribute the national values of emission. When this information is missing, the country average capacity (of all plants) is assigned to the plant.

When using the Net Capacity of a plant as proxy for the real intensity of the activity, there exists the risk of over-estimating the assigned share of emitted pollutants, since this parameter gives information about the potential usage of the plant and not the real one. In order to assess this uncertainty, for few selected countries, we compared the S&P Global Platts Geodatabase (2015) to the European Pollutant Release and Transfer Register database (E-PRTR v8[2]).

This Europe-wide E-PRTR register collects information from all the European countries that are obliged to report annually emissions for 91 key pollutants from facilities emitting beyond certain thresholds.

It appeared that while there exists a general agreement between the two data-sets about the ranking of the main emitting plants, it is the E-PRTR database which actually assigns a higher share of the national emissions to its larger plants. This is due to the fact that only plants emitting beyond a certain threshold are included in the European Register, while the S&P Global Platts Geodatabase has a much more comprehensive coverage.

The general agreement between the two sources was also found by Denier van der Gon et al, 2010, who reported that 85%-89% of the emissions in an older version of E-PRTR (EPER) were connected to the S&P Global Platts Geodatabase.

The spatial distribution of NO_x emissions from Power Plants for each of the considered fuels is depicted in Figure 1. For the sake of visualisation, the emission values are presented at NUTS2 level for all the EU28 Member States.

The emissions from petroleum refining sectors were disaggregated using geo-referenced data as reported by the European Petroleum Refiners Association (CONCAWE, 2014) while the emissions from coke production processes and other energy industries were distributed according to the European Pollutant Release and Transfer Register database (E-PRTR v8). The methodology applied to extract and process data from E-PRTR is better detailed in the following paragraph relative to Industrial emissions (MS3 and MS4).

[2] http://prtr.ec.europa.eu/

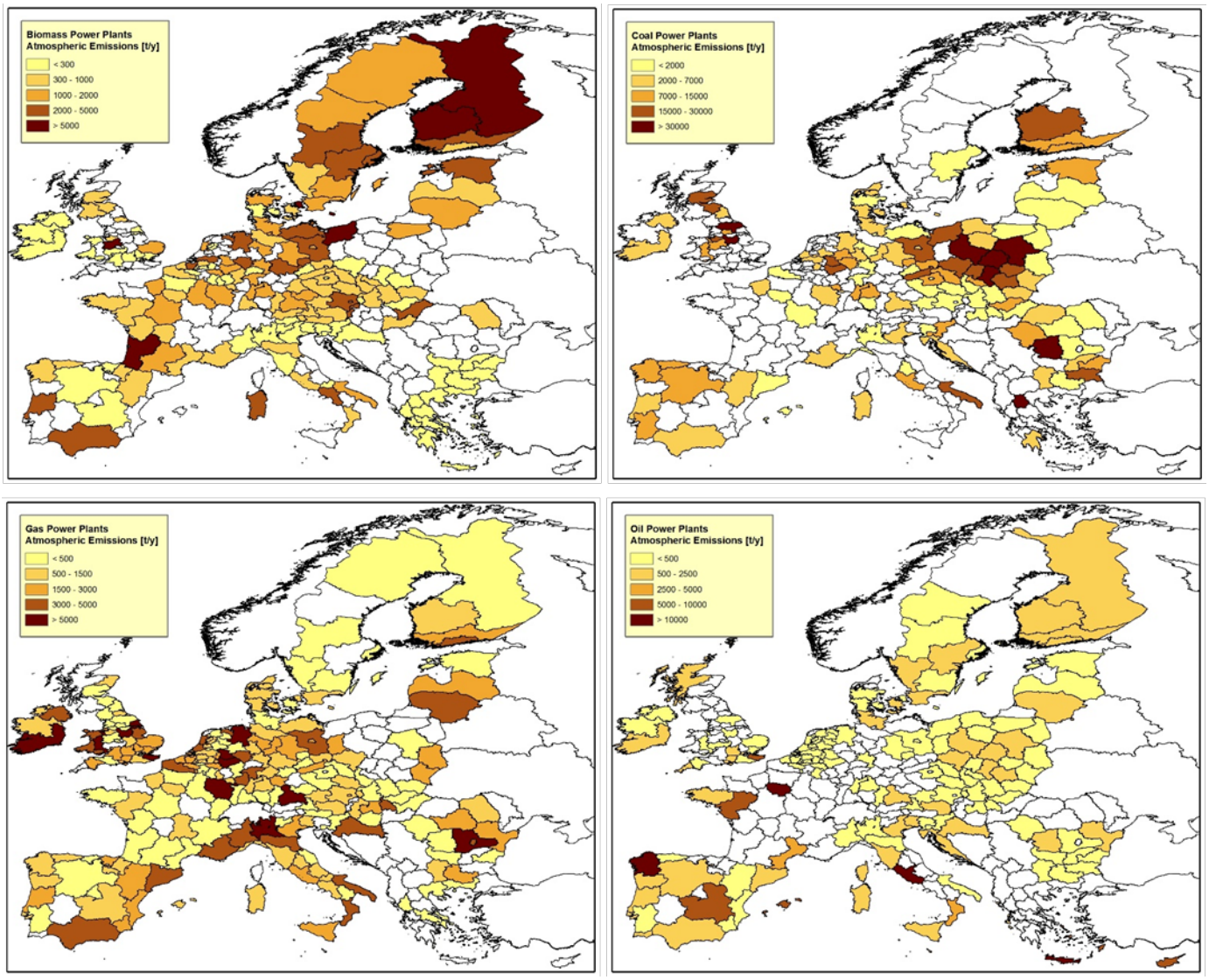

Figure 1: Atmospheric NOx emissions [t/y] from Energy Production represented at NUTS2 level. Energy data retrieved from the S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database

2.2.2 Macro Sector SNAP2 Non-industrial combustion

The sector-activity combinations which are part of the Economic Macro Sector SNAP2 (Non-Industrial combustion) include small combustion processes from residential and commercial plants as well as plants in agriculture. The emissions from this macro sector are mainly due to fuelwood and coal burning and are of crucial importance for certain pollutants (e.g.: $PM_{2.5}$, NO_x). Since they are linked to population density, their distribution in urban areas tend to be greatly over-estimated, leading to inaccurate assessment of air quality in urban areas (Timmermans et al., 2013).

Different approaches have been suggested in the past to correct these over-estimations.

The INERIS European scale Top-Down inventory (CTM4IAM version, Colette et al., 2015) developed a proxy based on population density weighted through a relationship between population and emission trained on French bottom-up data to reduce the importance of urban city centres in the downscaling process of these sector emissions. This relationship is then assumed to be valid and extended to the whole Europe (Colette et al., 2014).

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Biomass Power Plants	S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.A.1.a	PP_EX_OTH	Power & district heat plants - existing (excl. coal)	OS1	Biomass fuels
		1.A.1.a	PP_EX_OTH	Power & district heat plants - existing (excl. coal)	OS2	Biomass fuels
		1.A.1.a	PP_IGCC	Power & district heat plants - IGCC	OS1	Biomass fuels
		1.A.1.a	PP_IGCC	Power & district heat plants - IGCC	OS2	Biomass fuels
		1.A.1.a	PP_NEW	Power & district heat plants - new (excl coal)	OS1	Biomass fuels
		1.A.1.a	PP_NEW	Power & district heat plants - new (excl coal)	OS2	Biomass fuels
Coal Power Plants	S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.A.1.a	PP_EX_L	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	BC1	Brown coal/lignite grade 1
		1.A.1.a	PP_EX_L	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	BC2	Brown coal/lignite grade 2 (also peat)
		1.A.1.a	PP_EX_L	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	HC1	Hard coal, grade 1
		1.A.1.a	PP_EX_L	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	HC2	Hard coal, grade 2
		1.A.1.a	PP_EX_L	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	HC3	Hard coal, grade 3
		1.A.1.a	PP_EX_OTH	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	DC	Derived coal (coke, briquettes)
		1.A.1.a	PP_EX_S	Power & district heat plants, existing; coal/lignite fired, small units (< 50 MW th)	BC1	Brown coal/lignite grade 1
		1.A.1.a	PP_EX_S	Power & district heat plants, existing; coal/lignite fired, small units (< 50 MW th)	BC2	Brown coal/lignite grade 2 (also peat)
		1.A.1.a	PP_EX_S	Power & district heat plants, existing; coal/lignite fired, small units (< 50 MW th)	HC1	Hard coal, grade 1
		1.A.1.a	PP_EX_S	Power & district heat plants, existing; coal/lignite fired, small units (< 50 MW th)	HC2	Hard coal, grade 2
		1.A.1.a	PP_NEW	Power & district heat plants, existing; coal/lignite fired, large units (> 50 MW th)	DC	Derived coal (coke, briquettes)
		1.A.1.a	PP_NEW_L	Power & district heat plants, new; coal/lignite fired, large units (> 50 MW th)	BC1	Brown coal/lignite grade 1
		1.A.1.a	PP_NEW_L	Power & district heat plants, new; coal/lignite fired, large units (> 50 MW th)	BC2	Brown coal/lignite grade 2 (also peat)
		1.A.1.a	PP_NEW_L	Power & district heat plants, new; coal/lignite fired, large units (> 50 MW th)	HC1	Hard coal, grade 1
		1.A.1.a	PP_NEW_L	Power & district heat plants, new; coal/lignite fired, large units (> 50 MW th)	HC2	Hard coal, grade 2
Coke production and other Energy industries	E-PRTR v8, EEA, 2016	1.A.1.c	CON_COMB	Oth. En. Sect.: combustion	BC1	Brown coal/lignite grade 1
		1.A.1.c	CON_COMB	Oth. En. Sect.: combustion	DC	Derived coal (coke, briquettes)
		1.A.1.c	CON_COMB	Oth. En. Sect.: combustion	HC1	Hard coal, grade 1
		1.A.1.c	CON_COMB	Oth. En. Sect.: combustion	WSFNR	Waste fuels, non-renewable
		1.A.1.c	CON_COMB1	Fuel production : Combustion, grate firing	BC1	Brown coal/lignite grade 1
		1.A.1.c	CON_COMB1	Fuel production : Combustion, grate firing	HC1	Hard coal, grade 1
		1.A.1.c	CON_COMB2	Fuel production : Combustion, fluidized bed	BC1	Brown coal/lignite grade 1
		1.A.1.c	CON_COMB2	Fuel production : Combustion, fluidized bed	HC1	Hard coal, grade 1
		1.A.1.c	CON_COMB3	Fuel production : Combustion, pulverized	BC1	Brown coal/lignite grade 1
		1.A.1.c	CON_COMB3	Fuel production : Combustion, pulverized	HC1	Hard coal, grade 1
		1.B.1.a	STH_COAL	Storage and handling: Coal	NOF	No fuel use
Gas Power Plants	S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.A.1.a	PP_ENG	Power & district heat plants with internal combustion engines	GAS	Natural gas (incl. other gases)
		1.A.1.a	PP_ENG	Power & district heat plants with internal combustion engines	GAS_M	Natural gas (incl. other gases without bio gas)
		1.A.1.a	PP_EX_OTH	Power & district heat plants existing, non-coal; for GAS - boilers	GAS	Natural gas (incl. other gases)
		1.A.1.a	PP_MOD	Modern power plants (coal: ultra- and supercritical; gas: CCGT)	GAS	Natural gas (incl. other gases)
		1.A.1.a	PP_NEW	Power & district heat plants new, non-coal; for GAS - turbines	GAS	Natural gas (incl. other gases)
Oil Power Plants		1.A.1.a	PP_ENG	Power & district heat plants with internal combustion engines	HF	Heavy fuel oil
		1.A.1.a	PP_ENG	Power & district heat plants with internal combustion engines	MD	Medium distillates (diesel, light fuel oil)
		1.A.1.a	PP_ENG	Power & district heat plants with internal combustion engines	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
		1.A.1.a	PP_EX_OTH	Power & district heat plants existing, non-coal; for GAS - boilers	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.1.a	PP_EX_OTH	Power & district heat plants existing, non-coal; for GAS - boilers	HF	Heavy fuel oil
		1.A.1.a	PP_EX_OTH	Power & district heat plants existing, non-coal; for GAS - boilers	MD	Medium distillates (diesel, light fuel oil)
		1.A.1.a	PP_NEW	Power & district heat plants new, non-coal; for GAS - turbines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.1.a	PP_NEW	Power & district heat plants new, non-coal; for GAS - turbines	HF	Heavy fuel oil
		1.A.1.a	PP_NEW	Power & district heat plants new, non-coal; for GAS - turbines	MD	Medium distillates (diesel, light fuel oil)
Refineries	CONCAWE, 2014	1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	GAS	Natural gas (incl. other gases)
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	HF	Heavy fuel oil
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	LPG	Liquefied petroleum gas
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	MD	Medium distillates (diesel, light fuel oil)
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	OS1	Biomass fuels
		1.A.1.b	CON_COMB	Oth. En. Sect.: combustion	OS2	Other biomass and waste fuels
Waste Power Plants	S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.A.1.a	PP_EX_OTH	Power & district heat plants existing, non-coal; for GAS - boilers	WSFNR	Waste fuels, non-renewable
		1.A.1.a	PP_IGCC	Power & district heat plants: Integrated Gasification Combined Cycle	WSFNR	Waste fuels, non-renewable
		1.A.1.a	PP_NEW	Power & district heat plants new, non-coal; for GAS - turbines	WSFNR	Waste fuels, non-renewable

Table 2: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 1

Based on Dutch and Swedish data, Denier van der Gon et al. (2010) estimated that the wood use per person in rural areas is about 2 times higher than in urban areas in the TNO-MACCII inventory. In its updated version TNO MACCIII, any coal or fuelwood combustion was excluded from the city centres under the assumption that these activities are banned in many countries in Europe (Kuenen, personal communication).

The approach adopted in the JRC inventory follows Theloke et al., 2009, who use the degree of urbanization to weight the population distribution and hence as proxy for the potential domestic usage of fuel. The degree of urbanization layer[3] (DoU) is here used in its version at 1km spatial resolution. Based on geographical continuity and population density thresholds, the DoU layer classifies each grid cell as city (densely populated area), town/suburb (intermediate density area) or rural area (thinly populated area).

The population values modelled by LUISA are then weighted according to the assumption that in cities (as classified according to the degree of urbanization), usage of firewood in the domestic sector is remarkably lower than in rural areas, despite the much higher population density. Based on these input, weights are applied to the three degrees of urbanization (1 for cities and 3 for the rest of the inhabited areas), further differentiated with a ratio of 1 (towns and suburbs) to 10 (rural areas), in order to take into account the bans in urban centres existing in parts of Europe.

The usage of natural gas and coal burning is considered to be directly proportional to the population density, with equal weights for the three classes (Figure 2). For the sectors reporting agriculture and commercial plants emissions, 10% of the total emissions are assigned to the relevant land use classes (Industry and Agriculture) on the basis of the stratified estimates reported by GAINS.

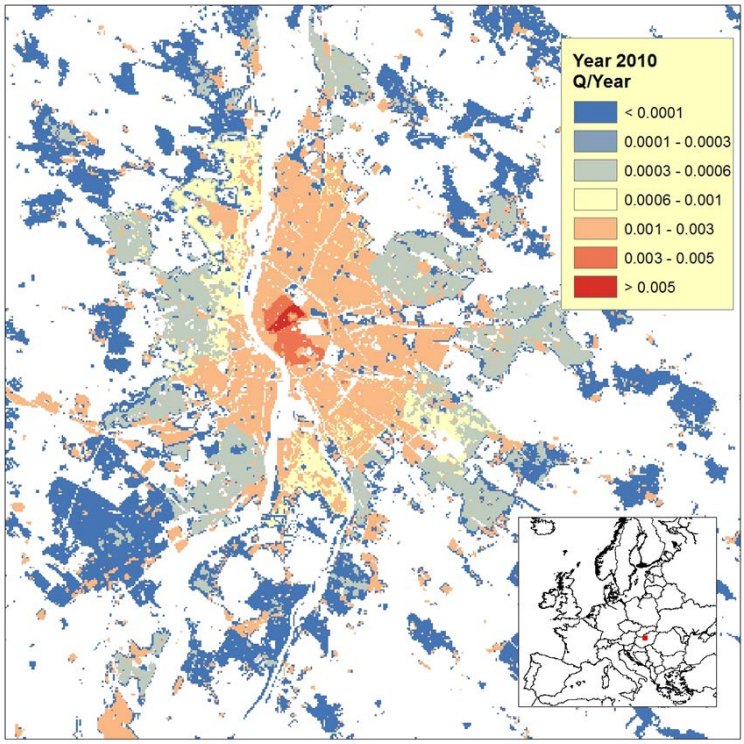

Figure 2: PM_{10} Emissions from Natural Gas in the residential sector

[3] http://ec.europa.eu/eurostat/web/degree-of-urbanisation/overview

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Population Density and industrial/agricultural land use	LUISA, Lavalle et al., 2013	1.A.4	DOM	Residential, commercial, services, agriculture, etc.	CHCOA	Charcoal
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	BC1	Brown coal/lignite grade 1
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	BIOG	Biogas
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	DC	Derived coal (coke, briquettes)
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	GAS	Natural gas
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	HC1	Hard coal, grade 1
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	HF	Heavy fuel oil
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	LPG	Liquefied petroleum gas
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	MD	Diesel
		1.A.4	DOM	Residential, commercial, services, agriculture, etc.	OS1	Biomass fuels
Population Density and industrial land use		1.A.4	DOM_MB_A	Medium boilers (<50MW) - automatic	BC1	Brown coal/lignite grade 1
		1.A.4	DOM_MB_A	Medium boilers (<50MW) - automatic	DC	Derived coal (coke, briquettes)
		1.A.4	DOM_MB_A	Medium boilers (<50MW) - automatic	HC1	Hard coal, grade 1
		1.A.4	DOM_MB_M	Medium boilers (<1MW) - manual	BC1	Brown coal/lignite grade 1
		1.A.4	DOM_MB_M	Medium boilers (<1MW) - manual	DC	Derived coal (coke, briquettes)
		1.A.4	DOM_MB_M	Medium boilers (<1MW) - manual	HC1	Hard coal, grade 1
		1.A.4	DOM_SHB_A	Single house boilers (<50 kW) - automatic	HC1	Hard coal, grade 1
		1.A.4	DOM_SHB_M	Single house boilers (<50 kW) - manual	BC1	Brown coal/lignite grade 1
		1.A.4	DOM_SHB_M	Single house boilers (<50 kW) - manual	DC	Derived coal (coke, briquettes)
		1.A.4	DOM_SHB_M	Single house boilers (<50 kW) - manual	HC1	Hard coal, grade 1
		1.A.4	DOM_STOVE_H	Heating stoves	BC1	Brown coal/lignite grade 1
		1.A.4	DOM_STOVE_H	Heating stoves	DC	Derived coal (coke, briquettes)
		1.A.4	DOM_STOVE_H	Heating stoves	HC1	Hard coal, grade 1
Weighted Degree of Urbanization and industrial land use	GISCO, EUROSTAT LUISA, Lavalle et al., 2013	1.A.4	DOM_FPLACE	Fireplaces	FWD	Fuelwood
		1.A.4	DOM_MB_A	Medium boilers (<50MW) - automatic	FWD	Fuelwood
		1.A.4	DOM_MB_M	Medium boilers (<1MW) - manual	FWD	Fuelwood
		1.A.4	DOM_SHB_A	Single house boilers (<50 kW) - automatic	FWD	Fuelwood
		1.A.4	DOM_SHB_M	Single house boilers (<50 kW) - manual	FWD	Fuelwood
		1.A.4	DOM_STOVE_C	Cooking stoves	FWD	Fuelwood
		1.A.4	DOM_STOVE_H	Heating stoves	FWD	Fuelwood

Table 3: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 2

2.2.3 Macro Sector SNAP34 Industrial combustion and processes

Emissions from industrial combustion (MS3) and industrial processes (MS4) have been kept aggregated because of the potential misclassification of emissions coming from these two macro sectors and also to facilitate the comparison with other inventories, such as the TNO MACC ones.

As a general rule industrial emissions are disaggregated on the basis of geo-referenced information extracted from the E-PRTR database, version 8.

Since not all emission sources are reported in E-PRTR, only a fraction of the GAINS modelled emissions can be distributed based on this register. The remaining part of the total national emission is instead considered as 'area source' or 'diffuse emission'. In order to compute the share of diffuse emissions with respect to the national totals, we divide the sum of emissions (grouped per SNAP sector for each chemical as reported by E-PRTR) by the total emission values reported by EMEP-CLRTAP for the same SNAP macro sector (Maes et al., 2009; Theloke et al., 2009).

This ratio represents the share of the GAINS national emissions that is considered as point source emissions, disaggregated according to the E-PRTR information. We also assume that the percentage of diffuse emissions remains constant in each of the GAINS sectors within a SNAP macro sector.

The remaining diffuse fraction is disaggregated using a surrogate for industrial emissions based on EUROSTAT employment statistics: Employment (in 1000 persons) by NUTS 3 regions (NACE Rev. 2)[4].

These data specify the number of employees per NUTS3 region in the NACE Activity 'Manufacturing' (C) (Eurostat, 2008). When these statistics are missing (France and United Kingdom), a 'flat' proxy based on industrial Land Use is used.

Within each NUTS3 region, the disaggregation at grid level is implemented on the basis of the Land Use Industrial class, as defined by the LUISA land use map, yielding to a dynamic layer for each of the considered years.

In order to extract point sources information from the E-PRTR database, a preliminary accuracy check on the database has been implemented. All points relative to offices and headquarters have been eliminated as well as all facilities with missing or wrong spatial information. Because E-PRTR is not reporting information for Croatia, all emissions have then been considered as diffuse emissions in this country.

The reporting year is 2010 and a surrogate has been generated for each of the activities reported in Table 4.

Other activities in this macro sector which are not covered by the E-PRTR database are:

- Construction activities: in this case employment statistics from EUROSTAT; Employment (in 1000 persons) by NUTS 3 regions (NACE Rev. 2) - NACE Activity 'Construction' (F) are used. Where these statistics are missing (UK), a 'flat' proxy based on industrial Land Use is used.

- Other industrial emissions and 'non energy' use of fuels: In this case a generic manufacturing activities surrogate is used, as defined above.

- Storage and handling and transport of mineral products: In this case a surrogate based on all transport infrastructures: internal and marine harbours, inland water and railway networks, freight air transport; local, national and e-roads, is used.

- Refineries: see procedure described in paragraph 2.2.1

[4] https://data.europa.eu/euodp/en/data/dataset/mUGHPaFSMwICQ6VagsK1pg

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Construction activities	EUROSTAT LUISA, Lavalle et al., 2013	2.A.7.b	CONSTRUCT	Construction activities	NOF	No fuel use
E-PRTR All manufacturing plants		1.A.2	IN_BO_OTH_L	Industry: other sectors; combustion of brown coal/lignite and hard coal in large boilers (> 50 MWth)	BC1	Brown coal/lignite grade 1
		1.A.2	IN_BO_OTH_S	Industry: other sectors; combustion of brown coal/lignite and hard coal in small boilers (< 50 MWth)	BC1	Brown coal/lignite grade 1
		1.A.2	IN_OC	Industrial furnaces	BC1	Brown coal/lignite grade 1
		1.A.2	IN_OC3	Industry: Other combustion, pulverized	BC1	Brown coal/lignite grade 1
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	BC1	Brown coal/lignite grade 1
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	DC	Derived coal (coke, briquettes)
		1.A.2	IN_OC	Industrial furnaces	DC	Derived coal (coke, briquettes)
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	DC	Derived coal (coke, briquettes)
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	GAS	Natural gas (incl. other gases)
		1.A.2	IN_OC	Industrial furnaces	GAS	Natural gas (incl. other gases)
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	GAS	Natural gas (incl. other gases)
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2	IN_OC	Industrial furnaces	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2	IN_BO_OTH_L	Industry: other sectors; combustion of brown coal/lignite and hard coal in large boilers (> 50 MWth)	HC1	Hard coal, grade 1
		1.A.2	IN_BO_OTH_S	Industry: other sectors; combustion of brown coal/lignite and hard coal in small boilers (< 50 MWth)	HC1	Hard coal, grade 1
		1.A.2	IN_OC	Industrial furnaces	HC1	Hard coal, grade 1
		1.A.2	IN_OC3	Industry: Other combustion, pulverized	HC1	Hard coal, grade 1
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	HC1	Hard coal, grade 1
		1.A.2	IN_BO_OTH_L	Industry: other sectors; combustion of brown coal/lignite and hard coal in large boilers (> 50 MWth)	HC2	Hard coal, grade 2
		1.A.2	IN_BO_OTH_S	Industry: other sectors; combustion of brown coal/lignite and hard coal in small boilers (< 50 MWth)	HC2	Hard coal, grade 2
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	HC2	Hard coal, grade 2
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	HF	Heavy fuel oil
		1.A.2	IN_OC	Industrial furnaces	HF	Heavy fuel oil
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	HF	Heavy fuel oil
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	LPG	Liquefied petroleum gas
		1.A.2	IN_OC	Industrial furnaces	LPG	Liquefied petroleum gas
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	LPG	Liquefied petroleum gas
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	MD	Medium distillates (diesel, light fuel oil)
		1.A.2	IN_OC	Industrial furnaces	MD	Medium distillates (diesel, light fuel oil)
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	MD	Medium distillates (diesel, light fuel oil)
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	OS1	Biomass fuels
		1.A.2	IN_OC	Industrial furnaces	OS1	Biomass fuels
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	OS2	Biomass fuels
		1.A.2	IN_OC	Industrial furnaces	OS2	Biomass fuels
		1.A.2	IN_BO_OTH	Industry: other sectors; combustion of fossil fuels other than brown coal/lignite and hard coal	WSFNR	Waste fuels, non-renewable
		1.A.2	IN_OCTOT	Industry: other combustion (all sectors)	WSFNR	Waste fuels, non-renewable
E-PRTR Aluminium production		1.A.2.b	PR_ALSEC	Ind. Process: Aluminum production - secondary	NOF	No fuel use
		2.C.3	PR_ALPRIM	Ind. Process: Aluminum production - primary	NOF	No fuel use
E-PRTR Bricks production		1.A.2.f.i	PR_BRICK	Ind. Process: Bricks production	NOF	No fuel use
E-PRTR Cast iron production		1.A.2.a	PR_CAST	Ind. Process: Cast iron (grey iron foundries)	NOF	No fuel use
E-PRTR Cement production		1.A.2.f.i	PR_CEM	Ind. Process: Cement production	NOF	No fuel use
E-PRTR Coke ovens		1.B.1.b	PR_COKE	Ind. Process: Coke oven	NOF	No fuel use
E-PRTR Coke production		1.A.1.c	IN_BO_CON	Industry, transformation sector, combustion in boilers	BC1	Brown coal/lignite grade 1
		1.A.1.c	IN_BO_CON	Industry, transformation sector, combustion in boilers	DC	Derived coal (coke, briquettes)
		1.A.1.c	IN_BO_CON	Industry, transformation sector, combustion in boilers	HC1	Hard coal, grade 1
		1.B.1.b	PR_BRIQ	Ind. Process: Briquettes production	NOF	No fuel use
		1.A.1.c	IN_BO_CON	Industry, transformation sector, combustion in boilers	OS1	Biomass fuels
E-PRTR Fertilizer plants	E-PRTR v8, EEA, 2016	2.B.5.a	FERTPRO	N - fertilizer production	NOF	No fuel use
		2.B.5.a	PR_FERT	Ind. Process: Fertilizer production	NOF	No fuel use
		2.B.5.b	STH_NPK	Storage and handling: N,P,K fertilizers	NOF	No fuel use
E-PRTR Food/Drinks production		2.D.2	FOOD	Food and drink industry	POP	Population
E-PRTR Generic chemical plants		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	BC1	Brown coal/lignite grade 1
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	DC	Derived coal (coke, briquettes)
		2.B.5.a	STCRACK_PR	Steam cracking (ethylene and propylene production)	EP	Ethylene and Propylene
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	GAS	Natural gas (incl. other gases)
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	HC1	Hard coal, grade 1
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	HF	Heavy fuel oil
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	LPG	Liquefied petroleum gas
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	MD	Medium distillates (diesel, light fuel oil)
		2.B.5.a	IO_NH3_EMISS	Other industrial NH3 emissions	NOF	No fuel use
		2.B.5.a	PR_CBLACK	Ind. Process: Carbon black production	NOF	No fuel use
		2.B.5.a	PR_OTHER	Ind. Process: Production of glass fiber, gypsum, PVC, other	NOF	No fuel use
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	OS1	Biomass fuels
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	OS2	Biomass fuels
		1.A.2.c	IN_BO_CHEM	Industry: chemical industry (combustion in boilers)	WSFNR	Waste fuels, non-renewable
E-PRTR Glass production		1.A.2.f.i	PR_GLASS	Ind. Process: Glass production (flat, blown, container glass)	NOF	No fuel use
E-PRTR Inorganic chemical plants		2.B.5.a	INORG	Inorganic chemical industry, fertilizers and other	EMI	Emissions of NMVOC
		2.B.2	PR_NIAC	Ind. Process: Nitric acid	NOF	No fuel use
		2.B.5.a	PR_SUAC	Ind. Process: Sulfuric acid	NOF	No fuel use
E-PRTR Iron/Steel production		2.C.1	PR_BAOX	Ind. Process: Basic oxygen furnace	NOF	No fuel use
		2.C.1	PR_CAST_F	Ind. Process: Cast iron (grey iron foundries) (fugitive)	NOF	No fuel use
		2.C.1	PR_EARC	Ind. Process: Electric arc furnace	NOF	No fuel use
		2.C.1	PR_HEARTH	Ind. Process: Open hearth furnace	NOF	No fuel use
		2.C.1	PR_PELL	Ind. Process: Agglomeration plant - pellets	NOF	No fuel use
		2.C.1	PR_PIGI	Ind. Process: Pig iron, blast furnace	NOF	No fuel use
		2.C.1	PR_PIGI_F	Ind. Process: Pig iron, blast furnace (fugitive)	NOF	No fuel use
		2.C.1	PR_SINT_F	Ind. Process: Agglomeration plant - sinter (fugitive)	NOF	No fuel use
E-PRTR Lime production		1.A.2.f.i	PR_LIME	Ind. Process: Lime production	NOF	No fuel use
E-PRTR Mining sites		2.A.7.a	MINE_OTH	Mining: Bauxite, copper, iron ore, zinc ore, manganese ore, other	NOF	No fuel use
E-PRTR Non-ferrous metal production		2.C.5	PR_OT_NFME	Ind. Process: Other non-ferrous metals prod. - primary and secondary	NOF	No fuel use
E-PRTR Organic chemical plants		2.B.5.a	OTH_ORG_PR	Organic chemical industry - downstream units	EMI	Emissions of NMVOC
		2.B.5.b	ORG_STORE	Organic chemical industry, storage	EMI	Emissions of NMVOC
E-PRTR Paper production		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	BC1	Brown coal/lignite grade 1
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	DC	Derived coal (coke, briquettes)
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	GAS	Natural gas (incl. other gases)
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	HC1	Hard coal, grade 1
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	HF	Heavy fuel oil
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	LPG	Liquefied petroleum gas
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	MD	Medium distillates (diesel, light fuel oil)
		2.D.1	PR_PULP	Ind. Process: Paper pulp mills	NOF	No fuel use
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	OS1	Biomass fuels
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	OS2	Biomass fuels
		1.A.2.d	IN_BO_PAP	Industry: paper and pulp production (combustion in boilers)	WSFNR	Waste fuels, non-renewable
E-PRTR Sinter plants		1.A.2.a	PR_SINT	Ind. Process: Agglomeration plant - sinter	NOF	No fuel use
E-PRTR Solvents usage		3.C	PVC_PR	Polyvinylchloride production by suspension process	PVC	PVC produced by suspension process
Manufacturing activities	EUROSTAT LUISA, Lavalle et al., 2013	7	NONEN	Nonenergy use of fuels	BC1	Brown coal/lignite grade 1
		7	NONEN	Nonenergy use of fuels	DC	Derived coal (coke, briquettes)
		2.A.6	IND_OTH	Other industrial sources	EMI	Emissions of NMVOC
		7	NONEN	Nonenergy use of fuels	GAS	Natural gas (incl. other gases)
		7	NONEN	Nonenergy use of fuels	GSL	Gasoline and other light fractions of oil (includes kerosene)
		7	NONEN	Nonenergy use of fuels	HC1	Hard coal, grade 1
		7	NONEN	Nonenergy use of fuels	HC2	Hard coal, grade 2
		7	NONEN	Nonenergy use of fuels	HF	Heavy fuel oil
		7	NONEN	Nonenergy use of fuels	LPG	Liquefied petroleum gas
		7	NONEN	Nonenergy use of fuels	MD	Medium distillates (diesel, light fuel oil)
		7	OTHER_CO2	Other CO2 emissions not included separately in GAINS and statistical differences	NOF	No fuel use
		7	OTHER_NOX	Other NOx emissions not included separately in GAINS and statistical differences	NOF	No fuel use
		7	OTHER_PM	Other PM emissions not included separately in GAINS and statistical differences	NOF	No fuel use
		7	OTHER_SO2	Other SO2 emissions not included separately in GAINS and statistical differences	NOF	No fuel use
		2.D.3	PR_SMIND_F	Ind. Process: Small industrial and business facilities - fugitive	NOF	No fuel use
Refineries	CONCAWE, 2014	1.B.2.a.iv	PR_REF	Ind. Process: Crude oil & other products - input to Petroleum refineries	CRU	Crude oil
		1.A.1.b	IN_BO_CON	Industry, transformation sector, combustion in boilers	GAS	Natural gas (incl. other gases)
		1.A.1.b	IN_BO_CON	Industry, transformation sector, combustion in boilers	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.1.b	IN_BO_CON	Industry, transformation sector, combustion in boilers	HF	Heavy fuel oil
		1.A.1.b	IN_BO_CON	Industry, transformation sector, combustion in boilers	LPG	Liquefied petroleum gas
		1.A.1.b	IN_BO_CON	Industry, transformation sector, combustion in boilers	MD	Medium distillates (diesel, light fuel oil)
		1.B.2.a.iv	PR_REF	Ind. Process: Crude oil & other products - input to Petroleum refineries	NOF	No fuel use
Transport infrastructures	GISCO, EUROSTAT OSM Contributors, 2015	2.A.7.c	STH_FEORE	Storage and handling: Iron ore	NOF	No fuel use
		2.A.7.c	STH_OTH_IN	Storage and handling: Other industrial products (cement, bauxite, coke)	NOF	No fuel use

Table 4: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 3 and 4

2.2.4 Macro Sector SNAP5 Extraction and distribution of fossil fuels

Information about coal mining and gas and oil extraction is extracted from the E-PRTR dataset, while the emissions from gas pipelines are distributed over the transmission network, as reported by S&P Global – Platts Geodatabase (provided by DG ENER, EMOS database). At this stage, no information about distribution and production grid is available.

Geo-referenced information about petrol stations was extracted from Open Street Map (OSM[5] contributors, 2015) through the 'geofabrik' website[6].

The fugitive emissions from the exploration, treatment, loading and also distribution of liquid and gaseous fossil fuels are distributed based on the location of marine and inland harbours, mining sites and gas pipelines (Table 5).

2.2.5 Macro Sector SNAP6 Solvents Use

Most of the emissions in this sector are released by industrial facilities and have been distributed using geo-location information extracted from the E-PRTR database, as described for Macro Sectors 3 and 4. The domestic use of solvents has been disaggregated based on population density while, for other applications, the urban and industrial land use classes have been used as surrogates (Table 6).

2.2.6 Macro Sector SNAP7 Road Transport

The downscaling of road transport emissions is based on road network data (OSM contributors, 2015), population density estimates (LUISA), highway traffic data (United Nations Economic Commission for Europe - UNECE) and TREMOVE model output.

The road networks are derived from Open Street Map (OSM contributors, 2015), distinguishing the following categories: motorways, national roads and regional/local roads. Land-use information as derived from the LUISA platform is then used to classify national and regional/local roads in terms of urban and not-urban types.

TREMOVE is a transport and emissions simulation model developed for the European Commission (De Ceuster et al., 2006) and it is used to distribute the GAINS country total emissions among the different network types (urban, not-urban and highway road). Among the different modules of the TREMOVE model, the 'fuel consumption and emissions' one has been considered the most appropriate for this task: this module is in fact used to calculate "fuel consumption and emissions, based on the structure of the vehicle stock, the number of kilometres driven by each vehicle type and the driving conditions".

This parameter is hence derived for each pollutant and for each of the 8 macro-categories of transport processes in which GAINS emissions have been grouped (Table 7) and used as a weight in order to distribute the national emissions between urban roads, non-urban roads and highways (E-roads). The original database is modified for Malta and Cyprus, in order to divide the emissions between urban and non-urban types only, since no road is classified as E-road, according to UNECE. Once the share of emission has been assigned to each of the three road types, information about traffic is needed to distribute it over the road network.

At present, no harmonised and consistent information seems to be available at European scale for urban, national and local roads. Population density has therefore been used as surrogate for these road typologies. We assume that the average population density in a buffer area around each grid point of the road network represents a good estimate of the potential usage (i.e. traffic) of that segment of road.

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[5] http://www.openstreetmap.org
[6] http://download.geofabrik.de/europe.html

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
E-PRTR Coal Mining sites	E-PRTR v8, EEA, 2016	1.B.2.b	CON_LOSS	Transformation - losses	HC1	Hard coal, grade 1
		1.B.2.b	CON_LOSS	Transformation - losses	HC2	Hard coal, grade 2
		1.B.1.a	MINE_BC	Mining: Brown coal	NOF	No fuel use
		1.B.1.a	MINE_HC	Mining: Hard coal	NOF	No fuel use
E-PRTR Gas extraction sites and pipeline network	E-PRTR v8, EEA, 2016 S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.B.2.b	EXD_GAS	Extraction, proc. and distribution of gaseous fuels	EMI	Emissions of NMVOC
E-PRTR Oil extraction sites and Refineries	E-PRTR v8, EEA, 2016	1.B.2.a.i	EXD_LQ	Extraction, proc. and distribution of liquid fuels	EMI	Emissions of NMVOC
		1.B.2.a.i	EXD_LQ_NEW	Extraction,proc.,distr.of lq.fuels (incl. new (Un)Load	EMI	Emissions of NMVOC
		1.B.2.b	CON_LOSS	Transformation - losses	HF	Heavy fuel oil
Gas transport network	S&P Global Platts Geodatabase (2015), provided by DG ENER, EMOS database	1.B.2.b	CON_LOSS	Transformation - losses	GAS	Natural gas (incl. other gases)
		1.B.2.b	EXD_GAS_NEW	Distribution of gaseous fuels - new mains	EMI	Emissions of NMVOC
Gasoline stations	OSM Contributors, 2015	1.B.2.a.v	D_GASST	Gasoline distribution - service stations	GSL	Gasoline and other light fractions of oil (includes kerosene)
Treatment and Distribution of fuel	GISCO, EUROSTAT E-PRTR v8, EEA, 2016	1.B.2.b	CON_LOSS	Transformation - losses	BC1	Brown coal/lignite grade 1
		1.B.2.b	CON_LOSS	Transformation - losses	DC	Derived coal (coke, briquettes)
		1.B.2.b	CON_LOSS	Transformation - losses	GSL	Gasoline
		1.B.2.b	CON_LOSS	Transformation - losses	MD	Diesel
		1.B.2.b	CON_LOSS	Transformation - losses	LPG	Liquefied petroleum gas
		1.B.2.a.v	D_REFDEP	Gasoline distribution - transport and depots (used in mobile sources)	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.B.2.a.v	D_REFDEP	Gasoline distribution - transport and depots (used in mobile sources)	MD	Medium distillates (diesel, light fuel oil)
		1.B.2.a.v	D_REFDEP_S	Gasoline distribution - transport and depots (used in stationary sources)	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.B.2.a.v	D_REFDEP_S	Gasoline distribution - transport and depots (used in stationary sources)	MD	Medium distillates (diesel, light fuel oil)

Table 5: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 5

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Industrial/Urban Land use	LUISA, Lavalle et al., 2013	3.A.1	DECO_P	Decorative paints	PNT	Paint use
		3.B.2	DRY	Dry cleaning	TEX	Textiles (clothing)
		3.B.2	DRY_NEW	Dry cleaning (new installations)	TEX	Textiles (clothing)
Population density		3.D.2	DOM_OS	Domestic use of solvents (other than paint)	POP	Population
		3.D.3	VEHTR	Treatment of vehicles	POP	Population
E-PRTR Solvents usage	E-PRTR v8, EEA, 2016	3.A.1	VEHR_P	Vehicle refinishing	PNT	Paint use
		3.A.1	VEHR_P_NEW	Vehicle refinishing (new installations)	PNT	Paint use
		3.A.2	AUTO_P	Manufacture of automobiles	VEH	Vehicles
		3.A.2	AUTO_P_NEW	Manufacture of automobiles (new installations)	VEH	Vehicles
		3.A.2	COIL	Coil coating (coating of aluminum and steel)	SC	Coated surface
		3.A.2	IND_P_CNT	Industrial paint applications - General industry (continuous processes)	PNT	Paint use
		3.A.2	IND_P_OT	Industrial paint applications - General industry	PNT	Paint use
		3.A.2	IND_P_PL	Industrial paint applications - General industry (plastic parts)	PNT	Paint use
		3.A.2	LEATHER	Leather coating	CTG	Coating
		3.A.2	WIRE	Winding wire coating	ENW	Enamelled wire
		3.A.2	WOOD_P	Wood coating	SC	Coated surface
		3.B.1	DEGR	Degreasing	SLV	Solvent use
		3.B.1	DEGR_NEW	Degreasing (new installations)	SLV	Solvent use
		3.C	PHARMA	Pharmaceutical industry	SLV	Solvent use
		3.C	PIS	Products incorporating solvents	PG	Paint and glue produced
		3.C	PLSTYR_PR	Polystyrene processing	EPS	Expandable polystyrene beads consumption
		3.C	SYNTH_RUB	Synthetic rubber production	RUB	Synthetic rubber
		3.C	TYRES	Tyre production	TYR	Tyres
		3.D.1	PRT_OFFS	Printing, offset	INK	Printing inks
		3.D.1	PRT_OFFS_NEW	Printing, offset, new installations	INK	Printing inks
		3.D.1	PRT_PACK	Flexography and rotogravure in packaging	INK	Printing inks
		3.D.1	PRT_PACK_NEW	Flexography and rotogravure in packaging, new installat	INK	Printing inks
		3.D.1	PRT_PUB	Rotogravure in publication	INK	Printing inks
		3.D.1	PRT_PUB_NEW	Rotogravure in publication, new installations	INK	Printing inks
		3.D.1	PRT_SCR	Screen printing	INK	Printing inks
		3.D.1	PRT_SCR_NEW	Screen printing, new installations	INK	Printing inks
		3.D.3	FATOIL	Fat, edible and non-edible oil extraction	SD	Seeds
		3.D.3	GLUE_INH	trial application of adhesives (use of high performance solvent based adhe	ADH	Adhesives
		3.D.3	GLUE_INT	dustrial application of adhesives (use of traditional solvent based adhesive	ADH	Adhesives
		3.D.3	IND_OS	Other industrial use of solvents	EMI	Emissions of NMVOC
		3.D.3	SHOE	Manufacturing of shoes	SHO	Shoes
		3.D.3	WOOD	Wood preservation (not creosote)	TIM	Wood treated
		3.D.3	WOOD_CR	Wood preservation (creosote)	TIM	Wood treated

Table 6: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 6

Ideally, the size of the buffer areas should be calibrated by country or, in the largest countries, by region, based on officially reported data. At this stage, a common size was selected for the whole EU28 domain: in the bigger countries buffer area is bigger for national roads (100 Km radius) than for local and urban ones (50 Km radius) due to the assumption that the potential catchment area of a national road is larger than the one of a local/urban road.

For highways, it was instead possible to use real traffic data, expressed as Average Annual Daily Traffic (AADT) per stretch of road (UNECE, 2005).

AADT is considered as one of the most important raw traffic datasets, as it provides essential inputs for traffic model developments and calibration exercises that can be used when planning new road construction, determination of roadway geometry, congestion management, pavement design, and many others. AADT is generally available for most of the European road networks. The data is collected by traffic control centres, refined and disseminated to users by traffic information centres in most of the EU countries.

The AADT database from UNECE covers different years, with 2010 as latest available. Because this update is not yet complete, 2005 data were used to populate our database, referring to previous years (2000 and 1995) to cover missing countries (Italy, Ireland, Netherlands and Denmark) and to gap-fill missing stretches of other countries.

Because The OSM E-roads network (i.e. highways) is more consistent with other road networks (national and regional) and it has a higher spatial accuracy, it appears to be more in line with our scope.

UNECE AADT traffic values are then assigned to the OSM highways network based on Euclidean distance between the two datasets. The traffic intensity value is then adapted proportionally to the number of road segments in the network per 100*100m^2.

In Figure 3 the spatial patterns of the weights applied to each of the road networks is shown for the city of Munich.

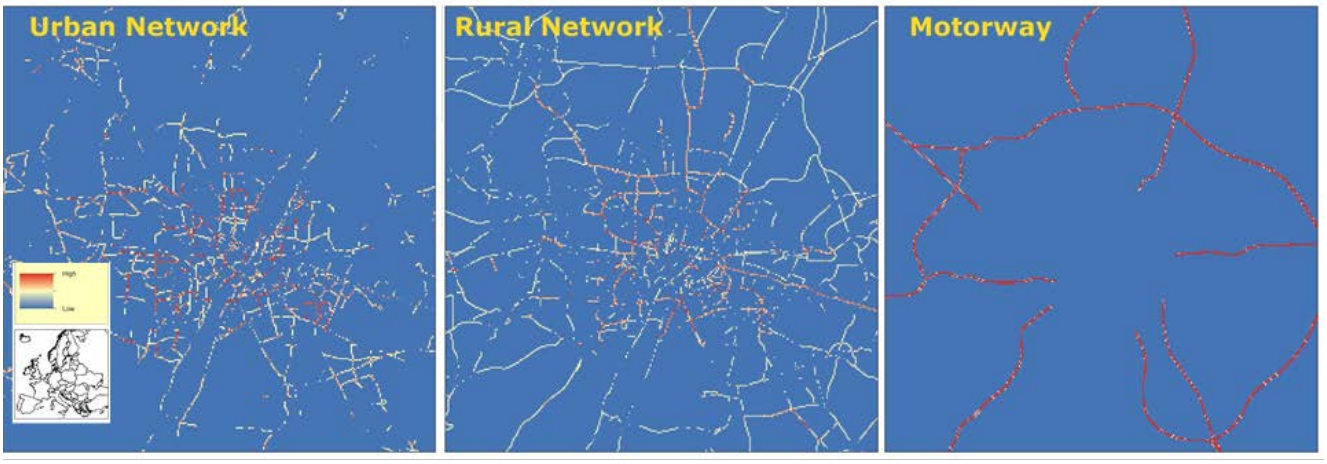

Figure 3: Road networks and applied weights for the city of Munich

For each of the 8 vehicle groups in TREMOVE (LDV diesel, LDV gasoline, LDV trucks, LDV –non-exhaust emissions, HDV bus, HDV trucks, Mopeds/Motorcycles/Cars 2 strokes, Motorcycles 4 strokes), the emission shares (for each emitted pollutant) assigned to the urban, non-urban and motorway road types can be calculated. This approach is valid for passenger vehicles but not for freight transport where population density is not the right proxy. Freight transport is assumed to be limited to highways.

2.2.7 Macro Sector SNAP8 Non-road transport and other mobile sources

In order to complement the GAINS database which only provides national shipping data international shipping emission data are taken from the EMEP database[7].

In this database, 2010 international shipping emissions are grouped by sea for all pollutants. For other years, only the domestic shipping emissions can be downscaled.

The values for international and national shipping are then summed up and treated as a unique shipping sector. Total emissions are downscaled using vessel density data, as elaborated by the JRC Maritime Affairs Unit based on information reported by vessels obliged to transmit Long-Range Identification and tracking system (LRIT) data. Alessandrini et al., 2016 provide a more exhaustive explanation of the used surrogate layer (shown in Figure 4).

Emissions from air traffic (only civil aviation is considered in GAINS) are disaggregated based on EUROSTAT data about freight and passengers transport (dataset 'Airport traffic data by reporting airport and airlines' [8]). Surrogates for passenger transportation and freight traffic are derived from these data.

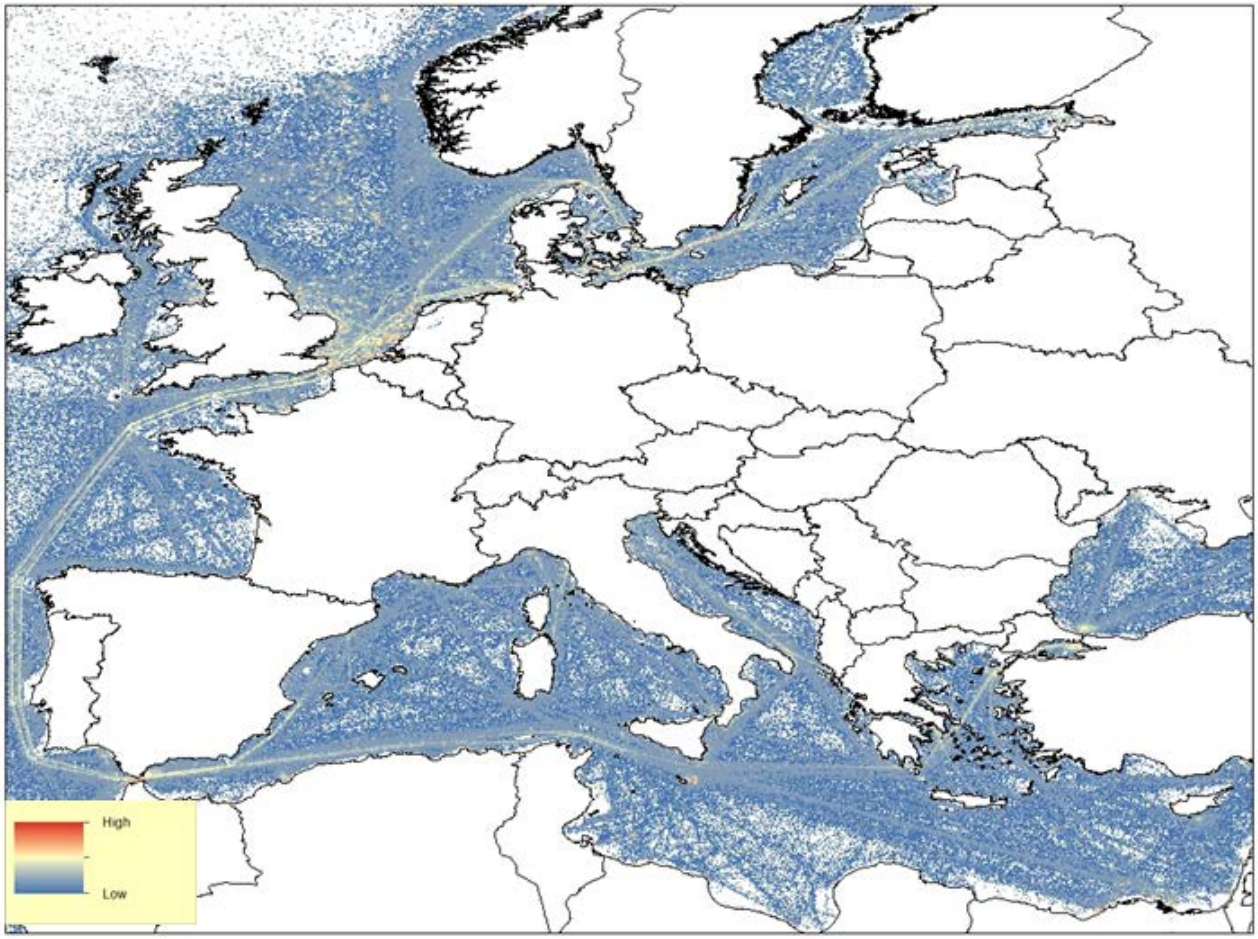

Figure 4: Vessel Density proxy used to downscale sea shipping emissions

[7] http://www.ceip.at/ms/ceip_home1/ceip_home/webdabemepdatabase/emissions_emepmodels

[8] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=avia_tf_apal&lang=en

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Car/Small Buses Gas and Gasoline	LUISA, Lavalle et al., 2013 TREMOVE, De Ceuster et al., 2006 UNECE, 2005 OSM Contributors, 2015	1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	LPG	Liquefied petroleum gas
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	GAS	Natural gas (incl. other gases)
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	GAS_M	Natural gas (incl. other gases without bio gas)
		1.A.3.b.i	TRA_RD_LD4C_EV	Evaporative emissions from 4-stroke cars	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.iv	TRA_OT_EV	Evaporative emissions from gasoline vehicles	GSL	Gasoline and other light fractions of oil (includes kerosene)
Car/Small Buses Diesel		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Light Trucks		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	LPG	Liquefied petroleum gas
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	TYRE	Non exhaust PM emissions - tyre wear
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	GAS	Natural gas (incl. other gases)
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	GAS_M	Natural gas (incl. other gases without bio gas)
		1.A.3.b.ii	TRA_RD_LD4T_EV	Evaporative emissions from 4-stroke trucks	GSL	Gasoline and other light fractions of oil (includes kerosene)
Light Duty Vehicles and Motorcycles Non exhaust emissions		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.i	TRA_RD_LD4C	Light duty vehicles: cars and small buses with 4-stroke engines	TYRE	Non exhaust PM emissions - tyre wear
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.ii	TRA_RD_LD4T	Light duty vehicles: light commercial trucks with 4-stroke engines	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.iv	TRA_RD_M4	Motorcycles with 4-stroke engines	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.iv	TRA_RD_M4	Motorcycles with 4-stroke engines	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.iv	TRA_RD_M4	Motorcycles with 4-stroke engines	TYRE	Non exhaust PM emissions - tyre wear
Heavy Duty Vehicles - Buses		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	LPG	Liquefied petroleum gas
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	TYRE	Non exhaust PM emissions - tyre wear
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	H2	
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	GAS	Natural gas (incl. other gases)
		1.A.3.b.iii	TRA_RD_HDB	Heavy duty vehicles - buses	GAS_M	Natural gas (incl. other gases without bio gas)
Heavy Duty Vehicles - Trucks		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	LPG	Liquefied petroleum gas
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	TYRE	Non exhaust PM emissions - tyre wear
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	GAS	Natural gas (incl. other gases)
		1.A.3.b.iii	TRA_RD_HDT	Heavy duty vehicles - trucks	GAS_M	Natural gas (incl. other gases without bio gas)
2-stroke engines		1.A.3.b.iv	TRA_RD_LD2	Motorcycles, mopeds and cars with 2-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.iv	TRA_RD_LD2	Motorcycles, mopeds and cars with 2-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.b.iv	TRA_RD_LD2	Motorcycles, mopeds and cars with 2-stroke engines	ABRASION	Non exhaust PM emissions - road abrasion
		1.A.3.b.iv	TRA_RD_LD2	Motorcycles, mopeds and cars with 2-stroke engines	BRAKE	Non exhaust PM emissions - brake wear
		1.A.3.b.iv	TRA_RD_LD2	Motorcycles, mopeds and cars with 2-stroke engines	TYRE	Non exhaust PM emissions - tyre wear
4-stroke engines Motorcycles		1.A.3.b.iv	TRA_RD_M4	Motorcycles with 4-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.b.iv	TRA_RD_M4	Motorcycles with 4-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources

Table 7: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 7

The two surrogates are then averaged in order to derive a weighted one for all civil air traffic. The area of interest, considered as affected by Landing and Take Off emissions (LTO) has been extended to a buffer area of 5km radius around the airport (Caserini et al., 2008). The emissions of NO_x from airport activities are shown in Figure 5 for the metropolitan area of Milan.

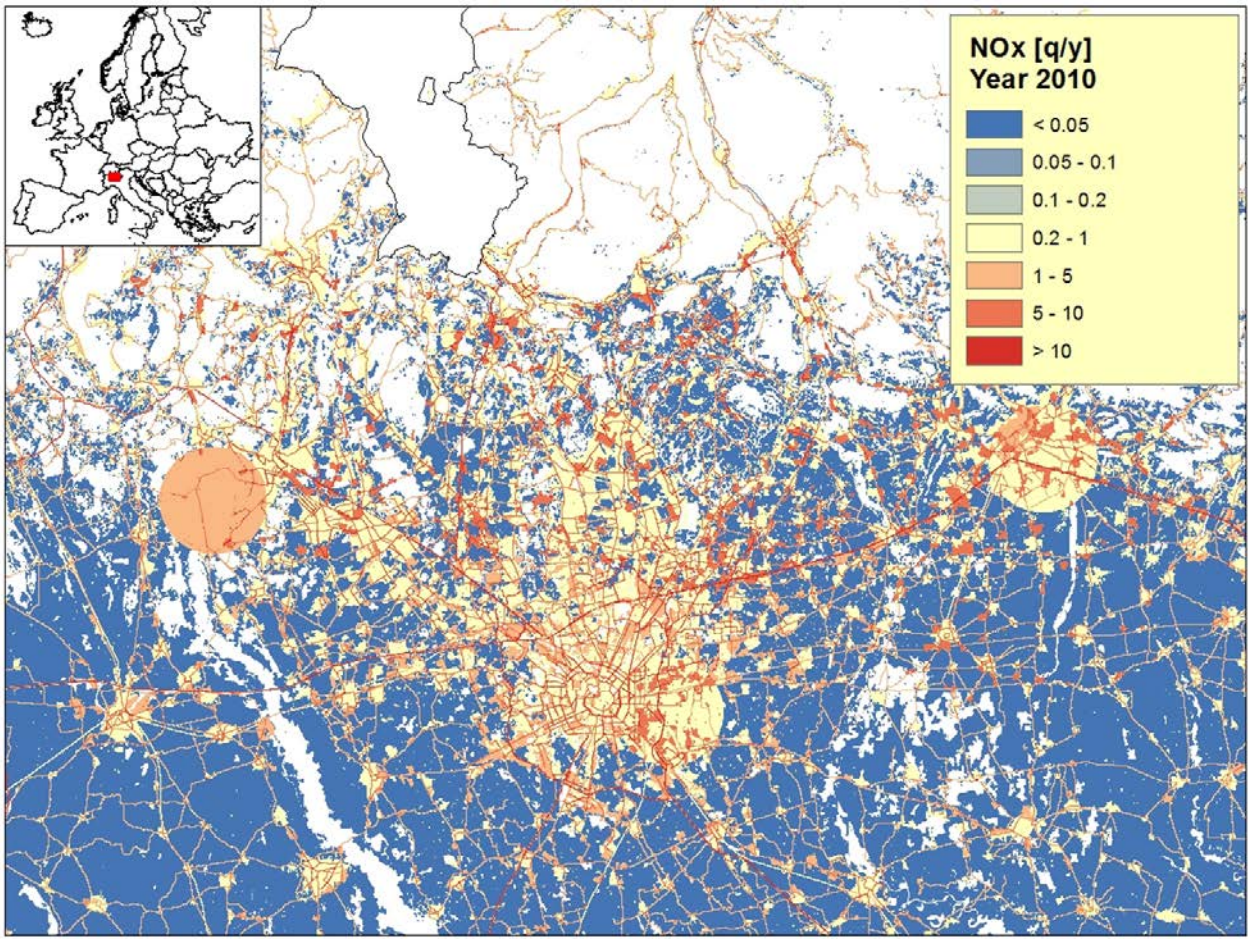

Figure 5: Total emissions of NO_x in the metropolitan area of Milano, served by three international airports

The TRANSTOOLS model[9] is the basis for disaggregating emissions from rail and inland waterways transport. Weights for these activities are based on a number of railway passengers per day and transported tonnes per day (rail and inland waterways).

Emissions from other off-road transport are instead disaggregated using generic surrogates, developed on the basis of land use classes or manufacturing activities.

2.2.8 Macro Sector SNAP9 Waste treatment

The main emissions source in this macro sector is waste treatment and disposal, including open burning of residential waste; the surrogate in this case is based on point sources as reported in the E-PRTR register, following the methodology introduced in the previous chapters. Emissions from gas flaring and oil industry are distributed among refineries and gas and oil extraction sites, while residential activities (cigarette smoking, fireworks and meat frying/food preparation) are associated to population density.

[9] http://energy.jrc.ec.europa.eu/transtools/TT_model.html

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Airport traffic	GISCO, EUROSTAT	1.A.3.a	TRA_OT_AIR	Other transport: air traffic - civil aviation	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.a.ii	TRA_OT_AIR_DOM	Other transport: domestic air traffic - civil aviation	GSL	Gasoline and other light fractions of oil (includes kerosene)
Inland Waterways traffic	TRANSTOOLS, JRC	1.A.3.d.ii	TRA_OT_INW	Other transport: inland waterways	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.d.ii	TRA_OT_INW	Other transport: inland waterways	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.d.ii	TRA_OT_INW	Other transport: inland waterways	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.d.ii	TRA_OT_INW	Other transport: inland waterways	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Manufacturing and Construction activities	EUROSTAT LUISA, Lavalle et al., 2013	1.A	TRA_OT	Non-road, other	HC1	Hard coal, grade 1
		1.A.2.f.ii	TRA_OT_CNS	Other transport: mobile sources in construction and industry	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.2.f.ii	TRA_OT_CNS	Other transport: mobile sources in construction and industry	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.2.f.ii	TRA_OT_CNS	Other transport: mobile sources in construction and industry	LPG	Liquefied petroleum gas
		1.A.2.f.ii	TRA_OT_CNS	Other transport: mobile sources in construction and industry	MD	Medium distillates (diesel, light fuel oil)
		1.A.2.f.ii	TRA_OT_CNS	Other transport: mobile sources in construction and industry	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Population Density and industrial/agricultural land use	LUISA, Lavalle et al., 2013	1.A.4.b.ii	TRA_OT_LD2	Other transport: off-road; sources with 2-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.4.b.ii	TRA_OT_LD2	Other transport: off-road; sources with 2-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	GAS	Natural gas (incl. other gases)
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	GAS_M	Natural gas (incl. other gases without bio gas)
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	MD	Medium distillates (diesel, light fuel oil)
		1.A.5.b	TRA_OT_LB	Other transport: other off-road; sources with 4-stroke engines	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Railways traffic	TRANSTOOLS JRC	1.A.3.c	TRA_OT_RAI	Other transport: rail	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.3.c	TRA_OT_RAI	Other transport: rail	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.3.c	TRA_OT_RAI	Other transport: rail	H2	Hydrogen
		1.A.3.c	TRA_OT_RAI	Other transport: rail	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.c	TRA_OT_RAI	Other transport: rail	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Sea shipping	JRC	1.A.3.d.ii	TRA_OTS_L	Other transport: maritime, large vessels, >1000 GRT	HF	Heavy fuel oil
		1.A.3.d.ii	TRA_OTS_L	Other transport: maritime, large vessels, >1000 GRT	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.d.ii	TRA_OTS_L	Other transport: maritime, large vessels, >1000 GRT	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
		1.A.3.d.ii	TRA_OTS_M	Other transport: maritime, medium vessels <1000GRT	MD	Medium distillates (diesel, light fuel oil)
		1.A.3.d.ii	TRA_OTS_M	Other transport: maritime, medium vessels <1000GRT	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)
Agriculture Land Use	LUISA, Lavalle et al., 2013	1.A.4.c.ii	TRA_OT_AGR	Other transport: agriculture and forestry	GSL	Gasoline and other light fractions of oil (includes kerosene)
		1.A.4.c.ii	TRA_OT_AGR	Other transport: agriculture and forestry	GSL_M	Gasoline and other light fractions of oil (includes kerosene), mineral fraction for mobile sources
		1.A.4.c.ii	TRA_OT_AGR	Other transport: agriculture and forestry	LPG	LPG
		1.A.4.c.ii	TRA_OT_AGR	Other transport: agriculture and forestry	MD	Medium distillates (diesel, light fuel oil)
		1.A.4.c.ii	TRA_OT_AGR	Other transport: agriculture and forestry	MD_M	Medium distillates (diesel, light fuel oil, mineral fraction for mobile sources)

Table 8: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 8

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Population Density	LUISA, Lavalle et al., 2013	3.D.3	RES_BBQ	Residential: Meat frying, food preparation, BBQ	NOF	No fuel use
		3.D.3	RES_FIREW	Residential: Fireworks	NOF	No fuel use
		7	OTH_NH3_EMISS	Other NH3 emissions	NOF	No fuel use
		3.D.3	RES_CIGAR	Residential: Cigarette smoking	NOF	No fuel use
E-PRTR Gas and Oil extraction sites and refineries	E-PRTR v8, EEA, 2016 CONCAWE, 2014	1.B.2.c	WASTE_FLR	Waste: Flaring in gas and oil industry	NOF	No fuel use
E-PRTR Waste treatment plants	E-PRTR v8, EEA, 2016	6.A	WASTE_VOC	Waste treatment and disposal	EMI	Emissions of NMVOC
		6.C.e	WASTE_RES	Waste: Open burning of residential waste	NOF	No fuel use
		6.D	WT_NH3_EMISS	Waste treatment and disposal	NOF	No fuel use

Table 9: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 9

2.2.9 Macro Sector SNAP10 Agriculture

Livestock emissions are disaggregated on the basis of FAO predicted data[10] (Robinson et al., 2014), which are modelled data adjusted to match officially reported subnational totals.

A separate surrogate has been built for cattle, poultry, pigs and other animals (sheep, horses) densities and combined with the LUISA land use information to constrain the livestock to suitable classes.

Two additional surrogates are then built for distributing emissions from the other agricultural activities. Proxies are derived from CAPRI (Britz, 2008; Britz and Witzke, 2008) modelled scenarios, similar to those used in LUISA for land allocation. Among the different available variables, the 'Yield [Kg]' was selected to explain the emission from ploughing, tilling, harvesting and waste burning activities, while the 'Fertilizer input per crop and ha (sum of managed, mineral, manure and other nitrogen)' for the emissions in the sectors relative to fertilizer use. All the values are modelled at NUTS2 level and the disaggregation from this level to 100m resolution is based on the 6 LUISA crop classes: Other Arable, Permanent Crops, Cereals, Maize, Root Crops, New Energy Crops.

An example of allocation of the main components for this Macro Sector to total NH_3 emissions is given in Figure 6 for a representative area of the United Kingdom.

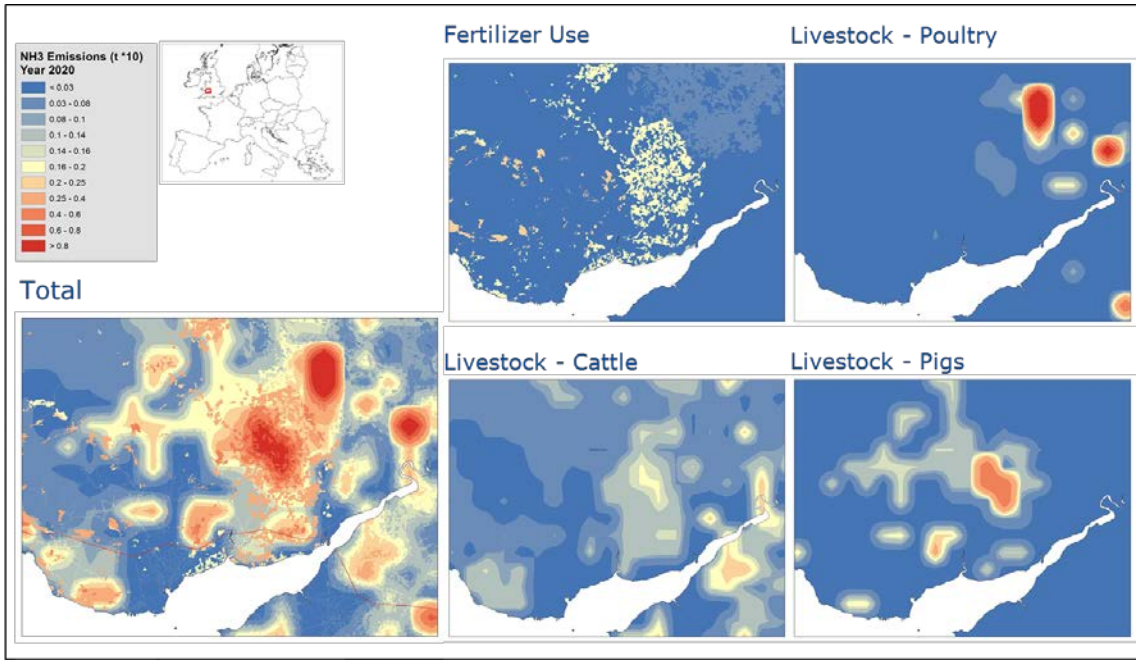

Figure 6: Main sectors contributing to the total NH_3 emissions in the south east of England.

[10] http://www.fao.org/ag/againfo/resources/en/glw/GLW_dens.html

Surrogate	Data Source	NFR_Codes	GAINS Sector	Sector description	GAINS Activity	Activity description
Agricultural land use	LUISA, Lavalle et al., 2013	4.D.2.a	STH_AGR	Storage and handling: Agricultural products (crops)	NOF	No fuel use
CAPRI fertilizer usage / Agricultural land use	CAPRI Model, 2012 LUISA, Lavalle et al., 2013	4.D.1	FCON_OTHN	Fertilizer use - other N fertilizers	NOF	No fuel use
		4.D.1	FCON_UREA	Fertilizer use - urea	NOF	No fuel use
CAPRI yield rate / Agricultural land use		4.D.1	AGR_ARABLE	Agriculture: Ploughing, tilling, harvesting, Arable agricultural land in temporal and subboreal climate	NOF	No fuel use
		4.F	WASTE_AGR	Waste: Agricultural waste burning	NOF	No fuel use
FAO Goats density	FAO, 2014	4.B.3	AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	SH	Sheep and goats
FAO Pigs density		4.B.8	AGR_PIG	Agriculture: Livestock - pigs	NOF	No fuel use
		4.B.8	AGR_PIG	Agriculture: Livestock - pigs	PL	Pigs - liquid (slurry) systems
		4.B.8	AGR_PIG	Agriculture: Livestock - pigs	PS	Pigs - solid systems
FAO Poultry density		4.B.9	AGR_POULT	Agriculture: Livestock - poultry	LH	Laying hens
		4.B.9	AGR_POULT	Agriculture: Livestock - poultry	NOF	No fuel use
		4.B.9	AGR_POULT	Agriculture: Livestock - poultry	OP	Other poultry
FAO Cattle density		4.B.1.a	AGR_COWS	Agriculture: Livestock - dairy cattle	DL	Dairy cows - liquid (slurry) systems
		4.B.1.a	AGR_COWS	Agriculture: Livestock - dairy cattle	DS	Dairy cows - solid systems
		4.B.1.a	AGR_COWS	Agriculture: Livestock - dairy cattle	NOF	No fuel use
		4.B.1.a	COWS_3000_MILK	Milk yield over 3000 kg/animal treshold	DL	Dairy cows - liquid (slurry) systems
		4.B.1.a	COWS_3000_MILK	Milk yield over 3000 kg/animal treshold	DS	Dairy cows - solid systems
		4.B.1.b	AGR_BEEF	Agriculture: Livestock - other cattle	NOF	No fuel use
		4.B.1.b	AGR_BEEF	Agriculture: Livestock - other cattle	OL	Other cattle - liquid (slurry) systems
		4.B.1.b	AGR_BEEF	Agriculture: Livestock - other cattle	OS	Other cattle - solid systems
FAO Generic Livestock density		4.B.13	AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	FU	Fur animals
		4.B.2	AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	BS	Buffalos
		4.B.3	AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	NOF	No fuel use
		4.B.6	AGR_OTANI	Agriculture: Livestock - other animals (sheep, horses)	HO	Horses

Table 10: GAINS Sector and Activities grouped by surrogate layers – Macro Sector SNAP 10

3 Conclusions

The JRC high-resolution emission inventory presented in this report constitutes an improved input for integrated assessment models in the field of air quality, as it provides high spatial and sectoral resolution and multi-temporal scenarios up to year 2030.

The inventory is produced with a spatial resolution of 100m and the values can then be aggregated to various resolutions. The inventory is currently released with nominal resolutions of 0.0625 degrees (~7km) and 0.1 degrees (~1km) to allow for their use in air quality models and to facilitate the comparison with other EU Top-Down inventories.

The methodological settings and choices adopted to build the spatial surrogates have been detailed for each macro sector with the aim of making the results transparent and interpretable.

Similarly to other emission inventories, the JRC inventory is not definitive and final. A regular updating process needs to take place. The input proxies and related calibrations will also need to be reviewed in parallel with the publication of new versions and updates of relevant databases and models (i.e., E-PRTR, TRANS-TOOLS, UNECE, PLATTS) and synchronised accordingly.

The JRC inventory will also need to be updated as new LUISA versions become available. LUISA is indeed the provider of the main drivers of our disaggregation methodology (Land use and Population density layers) and each time the LUISA reference scenario changes, the JRC emission inventory has to be updated accordingly.

In order to assess the robustness and the uncertainties of the proposed inventory, an extensive validation exercise is currently being carried on. The first part of this exercise focuses on urban areas (Trombetti et al., 2016) and on their most relevant macro sectors (Residential and Industrial Combustion, Road Transport). The comparison with the main Top-Down inventories for the European domain (TNO MACCII, TNO MACCIII, EMEP, INERIS, EDGAR) shows a consistent behaviour of our product; although distinctive behaviours linked to specific methodological choices do exist, the reported JRC emission trends appear to be in line with the other inventories.

Once this first part of the assessment will be completed, a validation for selected areas will be implemented at a higher spatial resolution, comparing our estimates with regional/local Bottom Up inventories. Besides providing further hints on the robustness of our inventory, this part of the validation will also provide specific feedback useful for shaping the disaggregation patterns in a more detailed way, allowing for the inventory to reflect national and regional trends.

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List of abbreviations and definitions

AADT Average Annual Daily Traffic

CAPRI Common Agricultural Policy Regionalised Impact

CONCAWE European Oil Company Organisation for Environment, Health and Safety

CORINAIR Core Inventory Air emissions

DoU Degree of Urbanization

EMEP European Monitoring and Evaluation Programme

EMOS Energy Market Observatory System (European Commission, Directorate-General for Energy)

CLRTAP Convention on Long-range Transboundary Air Pollution

EPER European Pollutant Emission Register

E-PRTR European Pollutant Release and Transfer Register

ETS Emissions Trading System

FAO Food and Agriculture Organization

GAINS Greenhouse Gas and Air Pollution Interactions and Synergies Model

HDV Heavy Duty Vehicles

IAM Integrated Assessment Modelling

LDV Light Duty Vehicles

LRIT Long-Range Identification and Tracking system

LTO Landing and Take-off

LUISA Land Use Integrated System Platform

MW MegaWatt

NACE Statistical classification of economic activities in the European Community

NUTS Nomenclature of Territorial Units for Statistics

OSM Open Street Map

RIAT Regional Integrated Assessment Tool

SHERPA Screening for High Emission Reduction Potential on Air

SNAP Selected Nomenclature for Air Pollution

TRANSTOOLS Tools for Transport Forecasting And Scenario testing

UNECE United Nations Economic Commission for Europe

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